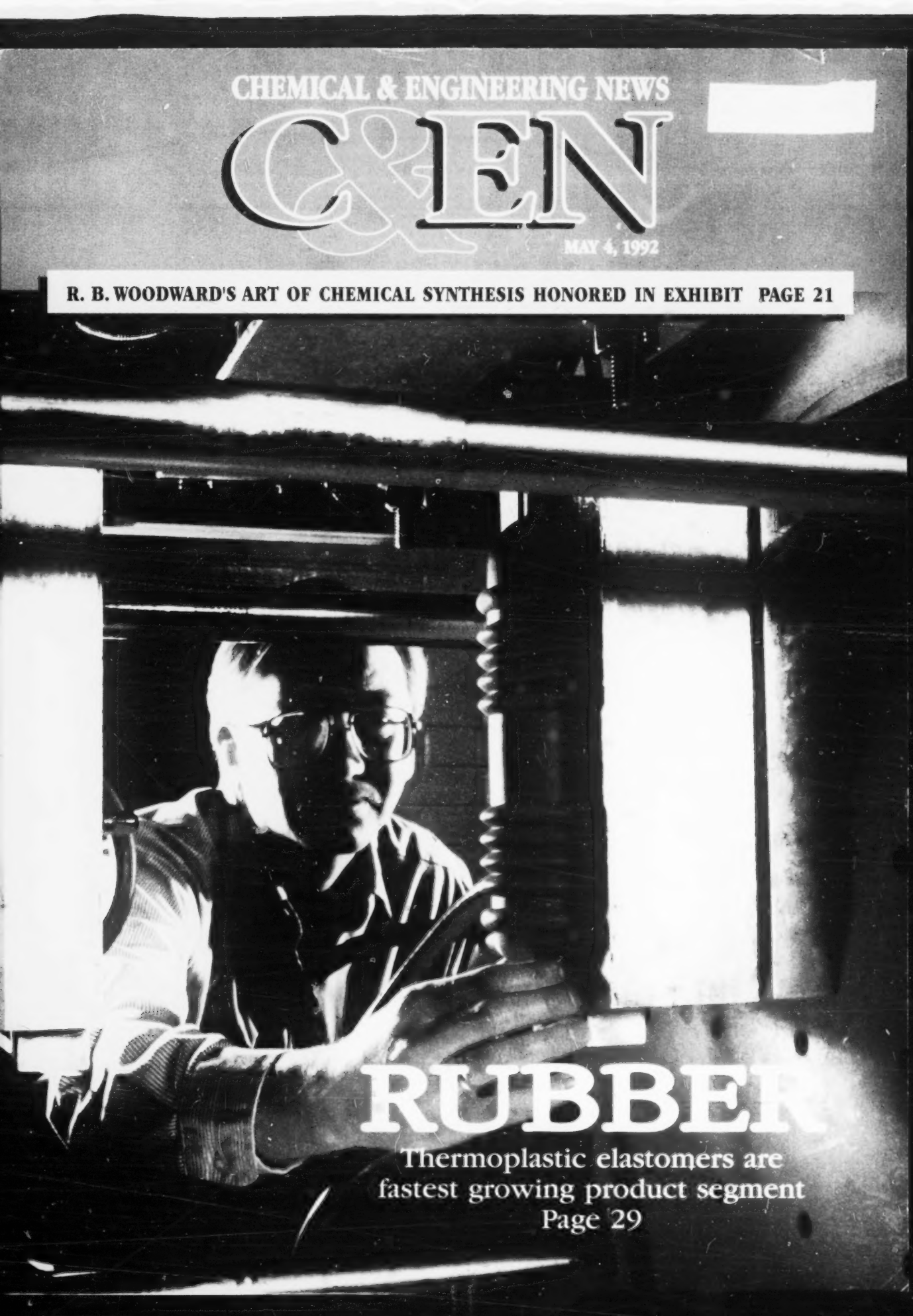
CHEMICAL & ENGINEERING NEWS

C&EN

MAY 4, 1992

R. B. WOODWARD'S ART OF CHEMICAL SYNTHESIS HONORED IN EXHIBIT PAGE 21



RUBBER

Thermoplastic elastomers are fastest growing product segment

Page 29

CHEMICAL & ENGINEERING NEWS

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NEWS OF THE WEEK

■ New Administration analysis suggests U.S. may come close to stabilizing CO_2 emissions at 1990 levels by year 2000 via existing programs. **Page 4**

■ Many chemists are among the 59 new members and 14 foreign associates elected to the National Academy of Sciences. **Page 4**

■ Detection of minuscule variations in temperature across vast regions of space lends credence to the Big Bang theory of the formation of the universe. **Page 5**

■ Protesters, including a host of demonstrative groups and individuals, turned Du Pont's annual meeting last week into a very lively affair. **Page 6**

■ New family of fullerene-uranium endohedral complexes synthesized, including small C_{28}-uranium complex. **Page 6**

COVER: Researcher at Advanced Elastomer Systems tests thermoplastic elastomer part

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National Science Foundation's announcement of proposed Critical Technologies Institute expected soon, as plans coalesce regarding its mission, management. **Page 15**

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PRODUCT REPORT

Thermoplastic elastomers, fastest growing segment of rubber industry, are replacing traditional synthetic and natural rubber in many uses, primarily because of recyclability and ease of processing. Page 29

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LETTERS

The job interview

I have been reading with interest the letters concerning the poor treatment of interviewees for industrial positions. I have been exposed to this process recently during my own job search, and would like to say that during five interviews, I have been treated with dignity and respect by everyone with whom I have met.

However, I am sorry to say that the situation was quite different last fall when I applied for six academic positions at high-level research universities. I would like to relate my experiences for two reasons.

First, I wish to alert other faculty search committees to be aware of the candidate's perspective during this very difficult process. Second, I dare to suggest to those who bemoan the appalling lack of young chemists (especially women) in the pipeline that we are indeed out there; however, we may be ignored, or worse, pushed away as I was.

Of the six schools to which I applied in October 1991 for the position of assistant professor of analytical chemistry, one turned me down one month after receiving my application because they had already filled the position. From the wording of the rejection letter, I believe that the candidate was preselected and hired from the inside. I understand this occurs quite frequently, and I only wish that I had known this in advance so that I could have saved the postage.

Of the five remaining universities, two did not hire an analytical chemist at all, probably because these were open searches for assistant professors in all areas of chemistry and there seems to be an abundance of qualified candidates compared to the number of available slots.

Two other search committees still have not bothered to contact me at all after five months! The only way I know of the status of these two applications is that I called the chairman of the respective search committees and inquired. In one of the two cases, the committee had lost two of my letters of recommendation (and claimed that they had never been received) although they never attempted to contact me to this effect. As such, my file remained incomplete and I was probably never considered as a candidate. I have found this kind of treatment to be rude, insulting, and dehumanizing to the candidate who anxiously checks the mail each day hoping for some word.

The sixth school brought me in for an interview in December. My experience began with the suggestion by my host that after arriving at the airport in a large midwestern city, I should make use of the public transportation system, which would deposit me several blocks away from the chemistry building with all my luggage in hand. I refused this suggestion, and requested to take a shuttle to my hotel in order to check in prior to the beginning of my interview that same day. I accepted this alternative as no one could (or would) come to the airport to pick me up, nor would anyone come to my hotel to bring me to the interview. (By distinct contrast, I remember being treated substantially better when I was a prospective graduate student visiting the different chemistry departments.)

The rest of the interview was unremarkable until the time of the dreaded "drill session," during which the faculty members question the candidate on the merit and viability of the proposed research. My session was scheduled over a one-hour lunch period on the second day of the interview. I was ushered into the faculty lounge where deli platters awaited; I then had food practically thrown onto my plate while I was told to eat as fast as I could since I would be presenting my proposals while everyone else was enjoying their lunch. I choked down my sandwich and began my presentation. I was very soon aware that of the 10 to 15 faculty members present, only one or two had bothered to read my proposals ahead of time, although they had been included with my application. I was caught by surprise at the overall ignorance of my audience, and I then spent an inordinate amount of time outlining my ideas when I should have been underscoring their scientific merit. When it was

Letters to the Editor

C&EN encourages readers to contribute to this letters section. However, please keep letters reasonably short—400 words or fewer. Because we receive a heavy volume of letters, persons writing letters are limited, as a general rule, to one letter within any given six-month period.

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Advanced Elastomer Systems photo

Thermoplastic Elastomers Bring New Vigor to Rubber Industry

Marc S. Reisch,
C&EN Northeast News Bureau

Use of traditional synthetic and natural rubber has struck a sort of balance over the past decade. Both categories of materials have shown growth in line with that of the gross national product. However, use of thermoplastic elastomers (TPEs) as direct replacements for traditional synthetic and natural rubbers is showing healthy growth, primarily because of ease of processing and fewer waste disposal problems.

For one, TPEs are more economical to produce than traditional thermoset materials, because fewer steps are required to manufacture them than to manufacture and vulcanize thermoset rubber. They are also easier to process on widely used and inexpensive plastic extrusion or injection-molding equipment, which gives faster production than slow-cycling, capital-intensive rubber processing equipment.

In addition, TPE factory scrap as well as postconsumer parts can be ground and reused. As a result, TPEs have, on the one hand, an economic advantage over traditional thermosets because the manufacturer has fewer waste disposal problems. On the other hand, their recyclability also endears them to environmental activists because the elastomers need not go into landfills or incinerators. Also, engineers can design parts using a wide range of TPEs from styrenics to high-performance polyamides. And within the individual classifications of TPEs, engineers can choose from a variety of performance criteria.

Very few TPE manufacturers would argue, however, that their product will replace all traditional rubber uses. TPEs do not have the wide temperature performance range of thermoset rubbers. In addition, their compression set, solvent resistance, and deformation resistance at high temperatures are generally not so good as those of cured thermoset elastomers. Consequently, TPEs are not used in tires. According to the International Institute of Synthetic Rubber Producers (IISRP), Houston, tire and tire products consume almost three quarters of the world's natural rubber and almost half of synthetic rubber annually.

Last year, the worldwide recession cut into demand for traditional thermoset rubber. World rubber consumption in 1991 declined almost 5% from 1990 to 14.2 million metric tons, according to IISRP. About 65% of rubber consumed in 1991 was synthetic rubber, such as styrene-butadiene or polybutadiene. Synthetic rubber demand in 1991 totaled 9.2 million metric tons, down almost 7% from 1990. Natural rubber consumption, at 5 million metric tons

last year, was essentially unchanged from 1990, and made up some 35% of all rubber consumed.

IISRP regards thermoplastic elastomers as a "below-the-line" item, and does not count them in its totals for rubber. Adding IISRP's thermoplastic elastomer consumption figures to its traditional synthetic and natural rubber surveys gives a picture of a group of elastomers whose use is growing even during a world recession and whose use is projected to grow mostly at the expense of thermoset synthetic rubber. In 1991, TPE consumption rose 5% worldwide from the previous year to 707,000 metric tons. That would put TPE use at nearly 5% of worldwide elastomer consumption in 1991, with synthetic rubber at 62% and natural rubber at 33%. However, TPEs now account for 10% of all nontire uses and may grow to 12% by 1996.

IISRP projects that TPE consumption will increase to 923,000 metric tons by 1996, giving it almost 6% of the world rubber market, as opposed to 35% for natural rubber and 59% for synthetic rubber. Whereas IISRP projects TPE consumption will grow at more than 5% annually over the next five years, it forecasts world synthetic rubber consumption will rise only 1.5% annually to just under 10 million metric tons, and natural rubber consumption will increase a little more than 3% per year to almost 5.9 million metric tons in 1996.

In North America, TPEs have already taken nearly 8% of the rubber market. Without any domestic source of natural rubber, the North American market traditionally has used more synthetic rubber, and has been relatively quick to embrace TPEs, consuming nearly 40% of world production in 1991. IISRP projects the average annual growth rate in North America for TPEs at more than 7% through 1996, giving them a nearly 10% share of rubber consumption. Only ethylene-propylene and a miscellaneous category of other rubbers will grow or maintain their share of the North American market, predicts IISRP. All others—styrene-butadiene, polybutadiene, nitrile, polychloroprene, and even natural rubber—will lose market share as thermoplastic use grows. Because of TPE growth, an IISRP spokesman says the organization plans to expand its statistical program to gather more data on these elastomers. Its 51 member companies include many of the world's major TPE producers.

Howard Blum, vice president of consulting firm Chem Systems, Tarrytown, N.J., estimates the value of the global TPE market at $1.5 billion. TPE use is growing 5 to 10% a year, depending on the region of the world, he says, versus 2% annual growth for traditional thermosets. Different categories of TPEs are growing at different rates. Styrenic block copolymers, for instance, are the most widely used TPEs, with 1991 use of 295,000 metric tons in the U.S., Western Europe, and Japan, according to Blum. However, their growth rate will be closer to 5% a year between 1990 and 2000. Polyolefins, on the other hand, are gaining wider acceptance now. With 1991 demand at 189,000 metric tons, they are growing at an annual rate of about 7%. Copolyesters are among the fastest growing TPEs with an annual growth rate of over 9%. Copolyesters are the least used TPEs at present, but Chem Systems' market study, scheduled to be published this month, projects demand for copolyesters will grow from 28,000 metric tons in 1990 to 68,000 metric tons in 2000.

According to Blum, the styrenics are generally lower performing and are the lower priced materials of the TPEs. Next in performance and price are the polyolefins, then thermoplastic urethanes, and at the top of the list are the copolyesters. Fairly new on the scene are higher price-performance engineering nylon elastomers. Another class of elastomers is polyvinyl chloride blends with rubber such as nitrile. Blum says these blends may be considered TPEs if "they are not pushed too hard"—that is, if they are not stretched too far to recover to their original position. Mostly used in Japan, but not widely used elsewhere, the blends compete on the lower end of the price-performance scale, says Blum.

Within the types of TPEs, manufacturers offer a number of materials to fit a variety of performance criteria. Royal Dutch/Shell, the largest U.S. and worldwide supplier of styrenic block copolymers (SBCs), produces its Kraton SBCs in three subcategories: a styrene-butadiene-styrene used in shoe soles and as both asphalt and polymer modifiers; styrene-isoprene-styrene, mainly used as a hot-melt adhesive and pressure-sensitive adhesive; and styrene-ethylene-butadiene-styrene, a high-performance TPE that brings SBCs into the engineering realm of polymers, Blum says.

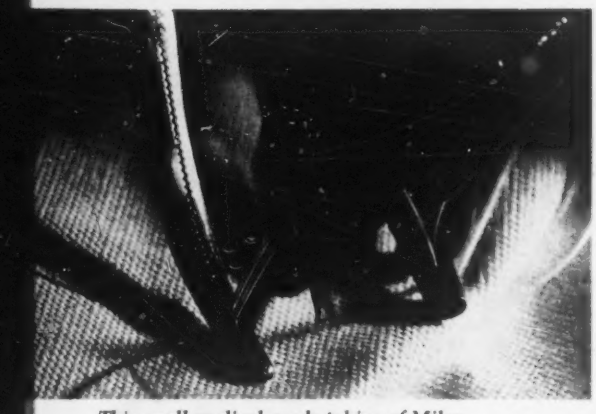
Charles P. Rader, a past chairman of the American Chemical Society's Rubber Division and a fellow in marketing and technical service for Advanced Elastomer Systems, says TPEs are "where the action is" in rubber use today. The ACS Rubber Division formed a thermoplastic elastomers group about four years ago to promote further development of them. One of the group's efforts has been to work with the Society of Automotive Engineers to set performance standards for factory regrind and recycled TPEs in automotive components.

The division's TPE group also plans a TPE symposium in November in Nashville, Tenn., says Rader. A reason

Demand for major thermoplastic elastomers to rise about 6% annually

Thousands of metric tons	1990	1991	2000	% annual change
Styrenic block copolymers	**284**	**295**	**448**	**4.7%**
U.S.	136	139	236	5.7
Western Europe	118	123	157	2.9
Japan	30	33	55	6.2
Polyolefins	**177**	**189**	**356**	**7.2%**
U.S.	75	81	196	10.1
Western Europe	80	84	126	4.6
Japan	22	24	34	3.5
Polyurethanes	**82**	**84**	**129**	**4.6%**
U.S.	30	29	44	3.9
Western Europe	42	44	69	5.1
Japan	10	11	16	4.3
Copolyesters	**28**	**30**	**68**	**9.1%**
U.S.	15	16	38	9.4
Western Europe	8	9	20	9.6
Japan	5	5	10	7.2
TOTAL	**571**	**598**	**1000**	**5.8%**

Source: Chem Systems



Thin-wall medical-grade tubing of Miles thermoplastic polyurethane is tough, flexible

for much of the interest, he says, is that use of TPEs has grown 8 to 9% annually since 1970. As a group, TPEs have replaced traditional thermosets such as styrene-butadiene rubber (SBR) and polychloroprene, he points out. Now two thirds of TPEs are direct replacements for thermosets and about another third are new uses.

Rubber processors who know the markets for elastomers have resisted the introduction of TPEs, Rader points out, because their machinery is not equipped to process thermoplastics. Plastics extruders and molders, who can easily process TPEs, do not know the rubber markets well enough to expand into elastomer production. Each, in general, has been slow to make either the investment or the effort to exploit these elastomers, he says.

But TPEs continue to see growth as they invade the traditional thermoset businesses. Bob Ackley, president of the Davis & Standard plastics extruding machinery division of Crompton & Knowles, says purchases of equipment to process TPEs "held their own during the recession," even though capital equipment purchases tend to be an up and down business depending on the economy.

And traditional thermoset rubber manufacturers are not necessarily displeased at the growth of TPEs. John R. Johnson, plastics market development manager for Uniroyal, notes the company has sold a lot of ethylene-propylene rubber (EPR) and ethylene-propylene-diene monomer (EPDM) to thermoplastic polyolefin (TPO) compounders as TPEs in some cases replace traditional thermosets. Where TPEs replace traditional EPDM (for instance, in a gasket), the EPDM incorporated into a TPE is often included at levels of 50 to 80% as opposed to 30% in a filled EPDM gasket, says Johnson.

Johnson expects good growth in EPDM and EPR both in the U.S. and Europe for use in TPEs. Uniroyal is currently heavily promoting the sale of these materials to TPO compounders supplying the automotive market in Europe. There, Johnson says, the recyclability of TPOs has helped them displace reaction-injection-molded urethane bumpers, particularly in Germany, where the push to use recyclable materials is particularly strong. Though copolyester compounds might make good bumpers, they are more expensive than TPOs. Nylon TPEs also could be used to make recyclable bumpers, but they are both expensive and unfamiliar to manufacturers for bumper use. TPOs, Johnson says, are the best low-cost alternative to urethanes. He estimates that TPOs now make up 80% of European-made auto bumpers, compared with 30% in the U.S. But U.S. autos hold more potential. He believes Ford, for instance, may convert much of its auto bumper production from reaction-injection-molded urethane to TPO by 1995.

Mike Stralkowski, marketing manager for Du Pont Elastomers, acknowledges that TPEs have been growing faster than thermosets with few exceptions. Stralkowski is in a good position to observe the competition between TPEs and thermosets because Du Pont straddles the line as a supplier of both traditional thermoset rubbers and thermoplastics. The company is the inven-

Glossary of thermoplastic elastomers

Thermoplastic elastomers—**A range of materials with properties of rubber and plastic. They are most often processed like conventional plastics in extrusion and injection-molding equipment, but have the flexural properties, tear strength, and abrasion resistance of rubber. However, thermoplastic elastomers (TPEs) generally have a serviceable temperature range of –95 to 340 °F, and are therefore not useful in very high temperature environments, a condition under which synthetic thermosets and natural latex are more suitable.**

Copolyesters—**Randomized block copolymers of polyester crystalline hard segments and amorphous glycol soft segments.**

Melt processible rubber—**Alloys of ethylene interpolymers and chlorinated polyolefins.**

Polyamides—**Combinations of rigid nylon blocks (of nylon 6, 66, 11, 12, and 612) and flexible polyether blocks. First introduced in the early 1980s, they are not as widely used as other TPEs.**

Polyolefins—**Blends of semicrystalline thermoplastic polyolefins and amorphous elastomers, often simply called TPOs. Combinations include polypropylene and copolymers with ethylene-propylene and ethylene-propylene-diene monomer elastomers. The majority of thermoplastic polyolefins are mechanically blended. TPOs may be further refined into:**

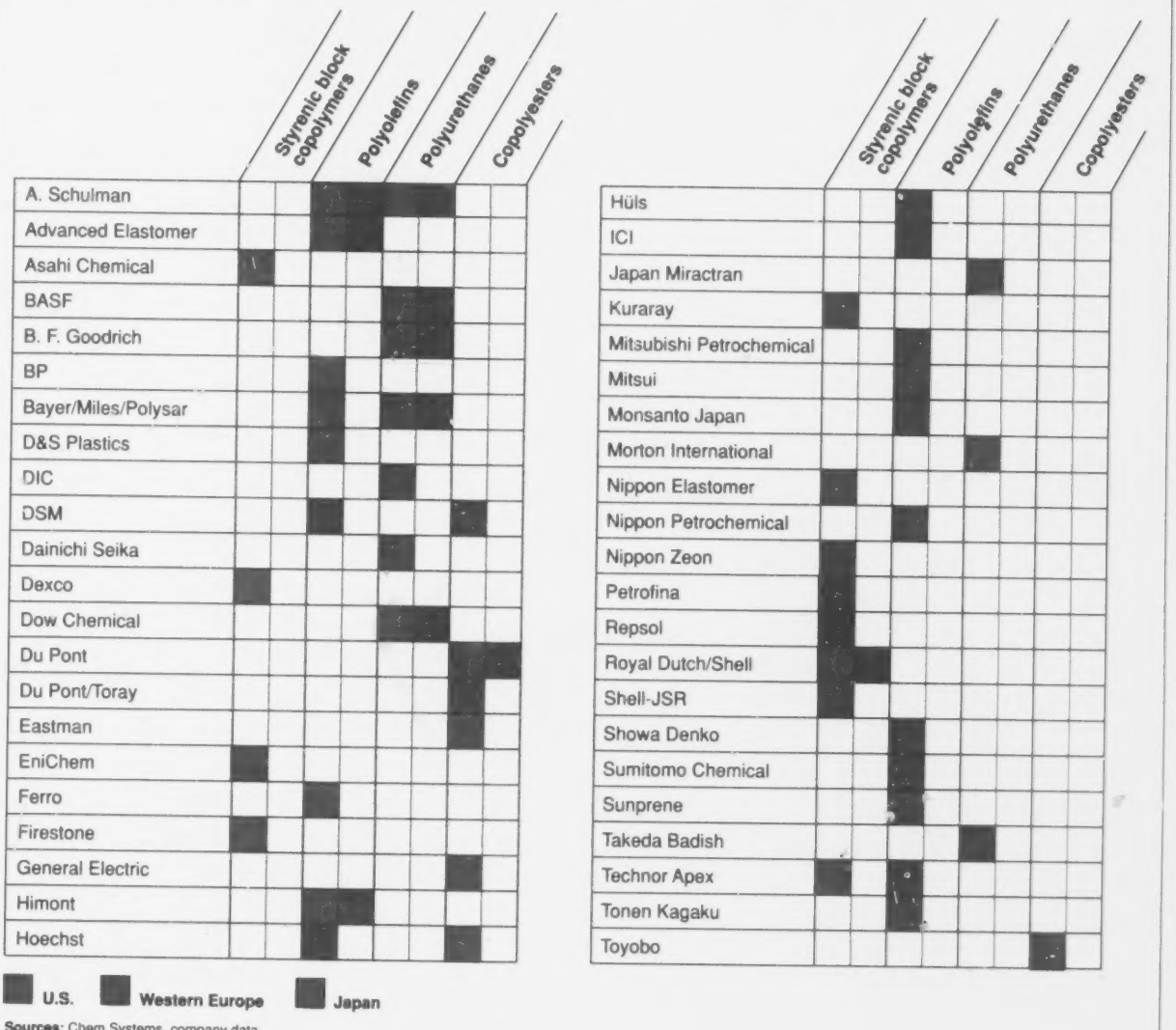
- Thermoplastic vulcanizates (TPVs)—**Mechanically compounded mixtures of polypropylene and a vulcanized rubber, such as ethylene-propylene-diene monomer.**
- Reactor-made TPOs—**Made in polypropylene copolymer reactors, these materials contain higher levels of ethylene-propylene rubber than mechanically compounded TPOs.**

Polyurethanes—**Fully reacted isocyanate block copolymers composed of either esters or ethers, depending on desired performance characteristics.**

Styrenics—**A widely used group of styrenic block copolymers that include styrene-butadiene-styrene block copolymers; styrene-isoprene-styrene block copolymers; styrene-ethylene/butylene-styrene block copolymers; and styrene-ethylene/propylene-styrene block copolymers.**

Vinyls—**Polyvinyl chloride blends with elastomers. More widely used in Japan, but gaining acceptance in other parts of the world.**

Diverse group of manufacturers supply thermoplastic elastomers



Sources: Chem Systems, company data

tor and major supplier of thermoset Neoprene (polychloroprene), and offers other thermosets such as ethylene acrylic elastomer and EPDM. It also supplies TPEs—Hytrel, a copolyester; Alcryn, a melt-processible rubber; and Zytel FN, a flexible nylon. In addition, Du Pont supplies intermediates that other manufacturers use to produce polyurethane TPEs.

The few exceptions in which use of thermosets is growing as well as that of TPEs involve specialty thermosets such as Viton fluoroelastomers, Vamac ethylene acrylic elastomers, and Acsium alkylated chlorosulfonated polyethylene, says Stralkowski. Both TPEs and thermosets have their place, he asserts. On a cost-per-pound basis, thermosets tend to be less expensive because they can be loaded with additives, such as carbon black. From a performance standpoint, they offer overall better resilience, compression set, and do not creep.

Offsetting these advantages, however, is that manufacturers of thermoplastic parts can make these parts in one-step extrusion or molding processes to finer engineering tolerances. Thermoset materials, however, must be mixed, and the parts extruded and then vulcanized. The multistep manufacturing process adds time and cost to parts manufacturing. In addition, says Stralkowski, thermoplastic scrap can be recycled into new parts. Thermosets cannot be recycled. Use of thermoplastics limits waste and saves manufacturers the disposal cost of unrecyclable thermoset materials.

Du Pont's copolyester TPE Hytrel competes against its own Neoprene polychloroprene for use in automotive drive boots. Like polychloroprene, the

copolyester will not break, stretch, or creep after continued flexing, says Stralkowski. Hytrel's use in drive boots is "an example of a high-performance thermoplastic penetrating the thermoset market," he says. Hytrel's dynamic properties make it a candidate for use in some belt applications and hydraulic hose. Its stability in environments where temperatures reach 300 °F also makes it a candidate for under-the-hood auto applications, unlike most other TPEs, Stralkowski says.

A change in automotive air-conditioning technology is also providing an opportunity for use of Du Pont's Xytel FN nylon TPE in air-conditioning hose. If thermoset rubber hose is used, the new hydrofluorocarbon refrigerant that will replace the chlorinated fluorocarbons now in use would leak. The new refrigerant systems will be in place next year. Stralkowski says Du Pont's Xytel FN is a candidate to form the inner layer of the hose holding the new refrigerant, whereas the outer layer will most likely remain a thermoset chlorobutyl rubber.

Global use of synthetic rubber to rise only 1.5% annually . . .

Thousands of metric tons	1991	1992	1996	% annual average growth 1991–96
Synthetic rubber[a]				
North America	2399	2484	2744	2.7%
Western Europe	2050	2068	2236	2.7
Asia & Oceania	1802	1851	2063	2.8
Latin America	553	586	638	2.9
Central Europe & former U.S.S.R.	1917	1649	1593	–3.6
Middle East & Africa	127	125	139	1.8
China/Asia	403	427	539	6.0
TOTAL	**9251**	**9190**	**9952**	**1.5%**

. . . while that of natural rubber to increase 3.3%

Thousands of metric tons	1991	1992	1996	% annual average growth 1991–96
Natural rubber[b]				
North America	846	889	987	3.1%
Western Europe	940	940	1020	1.6
Asia & Oceania	1955	1988	2281	3.1
Latin America	271	280	300	2.1
Central Europe & former U.S.S.R.	150	150	200	5.9
Middle East & Africa	165	170	190	2.9
China/Asia	668	708	894	6.0
TOTAL	**4995**	**5125**	**5872**	**3.3%**

a Excludes thermoplastic elastomers. b Excludes consumption by producing countries. **Source:** International Institute of Synthetic Rubber Producers

Bob Liskiewicz, markets and products director for Advanced Elastomer Systems (AES), the year-old $120 million Monsanto-Exxon joint venture, says the potential market for thermoplastic elastomers is about 3 million to 3.5 million metric tons annually, excluding the former Soviet bloc and China. But TPEs now have less than 10% of that market.

Developing markets for these elastomers is a time-consuming job, says Liskiewicz. Before they can replace synthetic rubber, for instance, a TPE manufacturer must show that a new TPE part would have properties equal to or better than the part it replaces. Automotive rubber parts are a major developing market for these elastomers, he says, where applications include auto air ducts, engine mounts, or rack and pinion steering linkage boots. Other potential markets for TPEs include electric tool housings, caster wheel treads, and handle grips, as well as dishwasher and washing machine parts.

Santoprene, a polyolefin thermoplastic vulcanizate, is AES's best-known product. AES compounds fully vulcanized EPDM with a polyolefin in a patented process to form Santoprene. The EPDM gives Santoprene its environmental and fluid resistance, says Liskiewicz, whereas the polyolefin component lends Santoprene easy plastics processing characteristics. Santoprene is an ideal replacement in many cases for polychloroprene and EPDM, he adds.

Santoprene's major advantage, as well as that of AES's other TPEs, such as Geolast, Trefsin, and Vistaflex, is that it processes so easily compared with rubber. "The advantage of a TPE is not the price, but the ease of processing," says Liskiewicz. If material prices were the only concern, "you would always go to rubber." The difference, he says, "is in processing time, which takes seconds for TPEs versus minutes for a comparable rubber part."

Because a number of rubber processors view TPEs as threats to their business, AES targets the product manufacturer to specify TPE parts, Liskiewicz says. Once a product manufacturer specifies a TPE part, a rubber processor may decide to take the plunge into TPE parts manufacture or it may end up losing the business to a plastics processor.

As patents on Santoprene expire and the competition in thermoplastic polyolefin vulcanizates (TPVs) heats up, Liskiewicz says AES hopes to become a leader in developing new applications for its TPE. For one, a design center in Akron, Ohio, will continue to assist customers in automotive, medical, and construction markets to develop new products. "We are dealing on an engineered level to compete with 'me-too' drop-ins," he says. Liskiewicz also sees good opportunities for TPVs in expansion joints on bridges and highways, and AES is working on specifications to develop performance criteria for TPE expansion joints.

John D. Cowperthwait, market development manager for Himont Advanced Materials, claims the company's Hifax polyolefin TPEs perform like Santoprene, but have better heat-aging characteristics and cost less than the AES product. Himont's TPEs are based on EPR and polypropylene, and as a result show good heat aging and chemical resistant characteristics, says Cowperthwait. In automotive applications, Himont's TPEs are used in shock absorber strut boots, air intake ducts, and as wire and cable coatings where they have replaced cross-linked polyethylene, he says. In addition, its TPEs are used in auto fascia and body side molding.

A new family of reactor-made cross-linked polyolefin TPEs is just now commercially available, says Cowperthwait, though the new Hifax XL line is still in the development phase and the full line is not yet available for

sale. The reactor-made material incorporates more EPR in the polypropylene relative to other polyolefin TPEs. An advantage of reactor-made polyolefin TPEs is their improved consistency.

Cowperthwait says that TPEs have done a fairly good job of replacing thermoset rubber in many applications, but only after TPE resin manufacturers put a great deal of effort into developing the market. When TPEs were first introduced, he was employed at Du Pont, which was then trying to introduce its Hytrel copolyester TPE to the rubber industry. Du Pont found that traditional thermoset rubber processors felt threatened by TPEs because they "antiquated" the rubber processors' equipment.

In addition, says Cowperthwait, most automakers only know what they expect rubber parts to do—to seal; to absorb energy, vibration, or noise; and to flex. But, he stresses, they don't know the specific performance characteristics of a particular rubber type, and so rely on the supplier to provide a part that will perform to their specifications. If an automaker's requirements specify fine engineering tolerances and recyclability, then the thermoset rubber parts processor will not be able to supply such a product.

Thus, to deliver a specified part, rubber processors have to make major investments in new equipment and possibly retire existing equipment. Even today, TPEs have only a few avid supporters among parts suppliers in the automotive market with a "knowledge base" sufficiently large to promote them, says Cowperthwait. They include some traditional rubber parts suppliers who realized they must develop TPE processing capability or slowly lose business, and some plastics parts suppliers who have recognized the potential and have taken the time to learn the rubber market, he says.

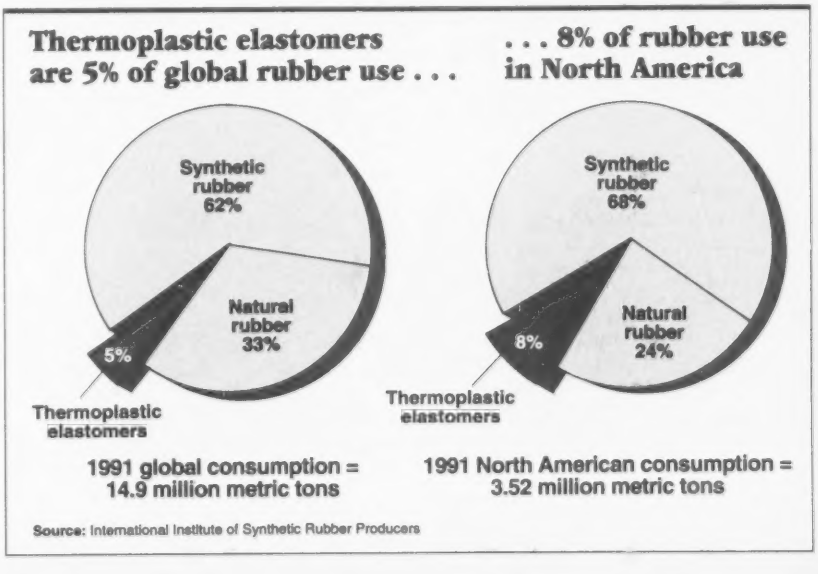
Although the recyclability of TPEs is often a selling point, Cowperthwait notes that the recyclability of postconsumer TPE materials is a matter European automakers pay more attention to than their American counterparts. Himont, in fact, recovers auto bumpers in Europe, which it regrinds and blends with virgin resins for resale under the tradename Refax. "There is no press in Detroit for recycling, unlike Europe, where car manufacturers such as BMW say they will not add more plastics to the cars they build until they figure out how to recycle the plastics," Cowperthwait says. In the U.S., he notes, current concern is more for recycling packaging materials.

Ferro's technology specialist, Paula M. Mokay, says the company has developed and recently introduced a new polypropylene TPE alloy that can be easily painted. Unlike other polyolefin TPEs that require surface treatment before painting, Ferro's new material can be made inherently polar and thus requires no primers or adhesion promoters before painting. Price is in the same range as conventional polyolefins. Mokay believes Ferro's as-yet-unnamed TPE will displace some TPVs and other TPEs now used in auto interior and exterior trim applications.

Hüls America's specialty polymers division produces a polyolefin TPV under the tradename Vestoprene. Roger W. Cash, specialty rubber marketing manager, characterizes Vestoprene as a Santoprene-type material. It is currently produced in Europe and is now available in the U.S. Cash says that Hüls is putting its R&D muscle into expanding applications and performance characteristics of its Vestoprene line to place it in markets other than the auto interior component and wire and cable coatings businesses it now competes in. Cash says Hüls is looking into a possible alliance with a domestic U.S. compounder who could make Vestoprene locally under a tolling arrangement. In addition, the company sells EPDM to U.S. TPE manufacturers.

A number of compounders are also involved in the TPE market. They include A. Schulman, of Akron, Ohio, and Technor Apex of Pawtucket, R.I. According to Alain Adam, vice president and automotive markets manager of A. Schulman, the company supplies polypropylene and EPDM-TPE blends under the Polytrope tradename for use as fascia, bumper covers, and body

Fabric used in Envirogear shelter consists of layers of nylon and Dow Pellethane polyurethane thermoplastic elastomer


Thermoplastic elastomers are 5% of global rubber use . . .
. . . 8% of rubber use in North America
Synthetic rubber 62%
Natural rubber 33%
5%
Thermoplastic elastomers
1991 global consumption = 14.9 million metric tons
Synthetic rubber 68%
Natural rubber 24%
8%
Thermoplastic elastomers
1991 North American consumption = 3.52 million metric tons
Source: International Institute of Synthetic Rubber Producers

Shell is latest to expand thermoplastic elastomers

With some markets growing "comfortably at double-digit rates," Anglo-Dutch chemicals giant Royal Dutch/Shell has committed nearly $115 million on a new plant for thermoplastic elastomers.

The plant, announced late last month, will be located at the company's chemicals complex at Berre, near Marseille, on the south coast of France. It will be the first commercial production by Shell outside the U.S. of its hydrogenated styrenic thermoplastic elastomers, sold under the Kraton G tradename. They are block copolymers of styrene with ethylene and butylene, or ethylene and propylene.

Shell has two other Kraton G plants, both in Belpre, Ohio, with combined capacity of 40,000 metric tons per year, currently being expanded to 45,000 metric tons. The Berre plant, scheduled to begin operating in early 1994, also will be able to produce Shellvis elastomeric viscosity index improvers, and a range of developmental thermoplastic elastomer products; total capacity will be more than 20,000 metric tons per year of product.

Shell's hydrogenated styrene elastomers are the "specialty" little brother of the company's other styrene block copolymers, sold under the Kraton D tradename in the U.S. and the Cariflex tradename in Europe. Total capacity for Kraton D—copolymers of styrene with butadiene or isoprene—is on its way to 280,000 metric tons per year: in the U.S., 80,000 metric tons at Belpre, now undergoing debottlenecking; 35,000 metric tons at Berre, being expanded to 60,000 metric tons; another 55,000 metric tons in the company's 50-50 joint venture with BASF, Rheinische Olefinwerke, at Wesseling, Germany; and 20,000 metric tons in Kashima, Japan, at Shell JSR Elastomers, the 50-50 joint venture of Shell and Japan Synthetic Rubber Co. In total, Shell claims to have more than 50% of the world market for thermoplastic elastomers.

As the sole producer of the hydrogenated elastomers, Shell is somewhat loathe to talk specifics about market sizes and growth. But company officials do point out that per capita consumption in Europe is only about one third that in the U.S. The specialty elastomers were introduced in Europe in about the mid-1980s, after being developed and marketed in the U.S. since the mid-1970s. Main end uses include adhesives and coatings, polymer modification, and in compounded form, a wide range of molded and extruded products.

"We think the market in Europe offers the same potential as that in the U.S.," says Peter E. Boorman, business manager for elastomers with Shell International Chemical Co., in London. The end uses in Europe are showing faster growth—some applications growing at double-digit rates—than in the U.S., albeit from a smaller base. "The expansions and the new capacity will be eaten up by the end of this decade," he predicts.

When the Berre plant starts up, he adds, it will join Belpre in supplying customers around the world. Given the fast growth of other consumer economies, will there be room for another Kraton G plant in Asia—in Japan, for example? "One of these days, that will be a good idea," says Boorman. "But there are absolutely no plans right now. We're going one at a time—this investment will supply demand for some time."

Patricia Layman

side molding. New grades of Polytrope will have a low coefficient of expansion for use in door side cladding so that extreme weather changes will not affect the fit of moldings. The company also supplies thermoplastic urethanes, obtaining the urethanes from Dow and filling or modifying them to customer specifications, says Adam. Priced at a premium compared with TPOs, the thermoplastic urethanes are easy to mold, have a very low coefficient of expansion, and paint easily without primer, says Adam.

Schulman also has a joint venture with Japanese compounder Mitsubishi Kasei, called Sunprene. The venture produces a mechanical blend of polyvinyl chloride and fillers to make what Adam calls a true PVC elastomer. Priced from $1.10 to $1.20 per lb, the PVC elastomers are supplied to parts suppliers of Japanese automakers with assembly operations in the U.S., says Adam. Sunprene goes after EPDM rubber applications such as weather seals and windshield reveal moldings.

Compounder Technor Apex is also producing what it calls PVC-TPEs under its own Ultraprene tradename. The Japanese have been most involved in PVC elastomers, says Lewis P. Green, plastics division marketing manager for Technor Apex. Only now are other manufacturers taking an interest in PVC, he says. In addition to PVC, Technor Apex sells specialty custom TPOs, TPVs, and SBCs. The company bought B. F. Goodrich's Telcar line of TPOs in 1980. It also produces SBCs made under license with Shell's Kraton polymers and sold under the Techron tradename for automotive dust covers, seals, trim, and knobs.

According to General Electric's applications technology engineer, Robert B. Johnson, the company's copolyester Lomod TPE covers the gap between low-end traditional rubbers and high-end thermoplastics. Lomod offers primerless paintability and better heat resistance than TPOs, he says. Lomod is aimed at five principal markets: sporting and consumer goods with a "soft touch" version, hose and tubing, sound and vibration dampers, flame-retardant enclosure applications, and auto fascias.

Although GE hopes to develop a large market for its copolyester in the automotive market by displacing TPOs, its high-gravity mineral-filled version of Lomod promises to replace metal in speaker enclosures. Johnson says Lomod has excellent sound and vibration damping abilities. Its use in speaker enclosures would displace metal or glass fiber now used there.

Like GE with Lomod and Du Pont with its Hytrel, Eastman also produces a copolyester TPE. Ecdel is aimed at medical applications, says Wayne Ladd, medical packaging business manager. Its principal niche is in use for drug packaging where less costly PVC packaging and its plasticizers could react with a drug and where the cost of the drug could support the higher price for Ecdel.

Dow Chemical's polyurethane TPE, Pellethane, is poised for moderate

growth says Stan Nerderman, Dow Plastics product manager. It is available in ester or ether versions depending on whether chemical resistance or hydrolytic stability is of more importance, he says. Its flexibility, low-temperature impact resistance, abrasion resistance, and paintability without a primer make it useful in industrial seals, gaskets, hose, auto body side moldings, and medical tube applications. Because it is at the high end of the price-performance curve, annual growth higher than 3% may not be possible. If, however, a good case can be made for polyurethanes in a volume use such as automotive side moldings, then polyurethane applications could grow at a much faster rate, says Nerderman.

A significant Dow competitor with a series of its own polyurethane TPEs is Miles' Texin urethane TPEs. Uses for Miles' (formerly Mobay) materials include automotive suspension system parts, medical tubing, cable jacketing, seals, and even horseshoes.

Elf-Atochem manufactures what it calls an engineering-grade TPE, Pebax. It is a nylon TPE similar to Du Pont's Xytel FN. Daryl G. Davis, product manager for Elf-Atochem, says Pebax is a versatile TPE that can incorporate a variety of polyamides (6, 66, 11, 12) and different polyethers to influence the performance characteristics of different Pebax grades. The material can be hydrophilic or antistatic, for instance, and

Auto axle boot of AES's Santoprene TPE outlast boots made from other rubbers

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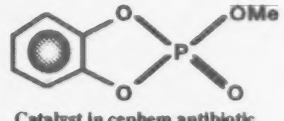
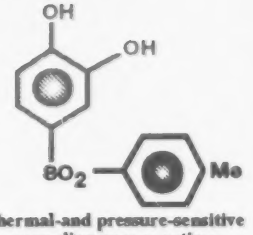
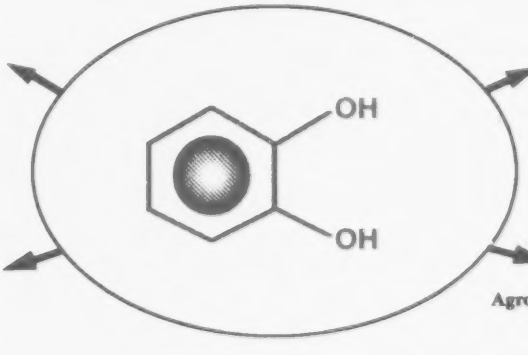
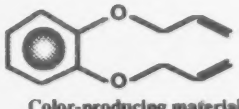


Catalyst in cephem antibiotic synthesis
JP 82-6668 (1984)

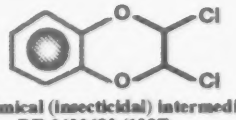


Thermal-and pressure-sensitive recording paper coating
JP 63119451 (1988)





Color-producing material in thermal recording system
JP 02000577 (1990)



Agrochemical (insecticidal) intermediate
DE 3602682 (1987)

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CIRCLE 14 ON READER SERVICE CARD

Bumper fascias on 1992 Pontiac Bonneville SSEi are molded of General Electric's Lomod copolyester thermoplastic elastomer offer heat resistance and paintability

gives service in temperature ranges between -40 and 80 °C. Medical applications include catheters, tubing, and film for transdermal patches and wound covers. Sports applications include athletic shoe soles and swim fins, and industrial uses include conveyor belts and bushings for shock absorption. Pebax, Davis says, is lighter than copolyester TPEs and competes with them as well as polyurethane TPEs. He believes demand for Pebax will grow 15 to 20% annually for the next several years.

Pebax, says Davis, has been available for the past 10 years in both Europe and North America. Its use in North America has increased dramatically in the past three years, he says. Elf-Atochem manufactures most grades of Pebax at a plant in Pennsylvania for the North American market, but imports some grades from plants in Europe. Users will specify a material such as Pebax, which is priced at the high end of the TPE market, because they want a high-performance material and are willing to pay the premium, he says.

Davis, like other marketers of TPEs, does not believe that TPEs will replace thermoset rubbers entirely either now or in the future. They are all confident, however, that TPE use will grow, most often at the expense of thermosets. Although TPEs have processing advantages over traditional thermoset products, their performance temperature ranges still restrict them from the major rubber market—car and truck tires. But where their recyclability and performance criteria satisfy specific market needs, their use will grow. TPEs, after all, are currently the most dynamic rubber market. □

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CIRCLE 29 ON READER SERVICE CARD

Marriage, Gender Influence Career Advancement for Chemists

■ ***Many married women compromise on their careers, either for family or because their gender hinders promotion***

Mairin Brennan, C&EN Washington

The results of a new survey by the American Chemical Society that examines the influence of family responsibilities and gender on career advancement suggest that compromise is the lot of dual-career families, especially those with children. And women do most of the compromising.

The survey uncovers some striking patterns: Among chemical professionals, married women are more likely than married men to view their spouse's career as more important than their own; married women are less likely than all other categories of chemists to rate financial necessity as important in a career; married women with children are the most likely to work part-time; and married women are more likely than married men to relocate for a spouse's career.

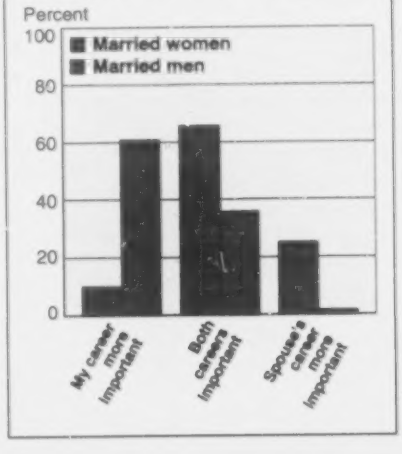
The survey also clearly shows that the issues of sex discrimination and sexual harassment are far from being laid to rest: Nearly half the women surveyed perceive gender as a roadblock to career advancement, and nearly 40% say they have encountered sexual harassment in the workplace, against themselves or against other women.

The survey was mailed last fall to 4200 chemists (2100 of each gender), selected on the basis of age and type of employer. Responses totaled 2851 (68%), with more women (72%) than men (64%) responding. The survey was prompted by ACS's analysis of its 1990 annual survey of the salary and employment of its members, which showed the same salary pattern as had existed 15 years before, when the society began its every-five-year analyses that monitor the status of women (C&EN, Oct. 21, 1991, page 31). To wit, starting salaries were about the same for both sexes, but women's salaries overall slid with years of experience compared with men's.

At the same time, the number of women entering chemistry continued to escalate—women earned 39% of B.S. and 25% of Ph.D. degrees in 1989 (the latest year for which statistical data are available) compared with 18% and 8%, respectively, in 1970. And women were moving into industrial employment in nearly the same proportion as men (63% of women versus 64% of men last year).

Despite these numerical gains, however, women have not made comparable inroads into management and the higher academic ranks. In 1975, 13% of Ph.D. women chemists in industry were in R&D management; in 1991 that figure dipped to 12%. In academia, 24% of Ph.D. women chemists were full professors in 1980 (rank was not asked in 1975); by 1991 this proportion had barely edged up (25%). Salaries, however, are nearly identical for men and women with the same length of experience doing the same work—for example, among Ph.D. industrial chemists in applied research, women's salaries are 98 to 100% of men's through 24 years following the B.S. degree. So the salary gap with years of experience seems related to differences in job function.

A fourth of married women put spouse's career first

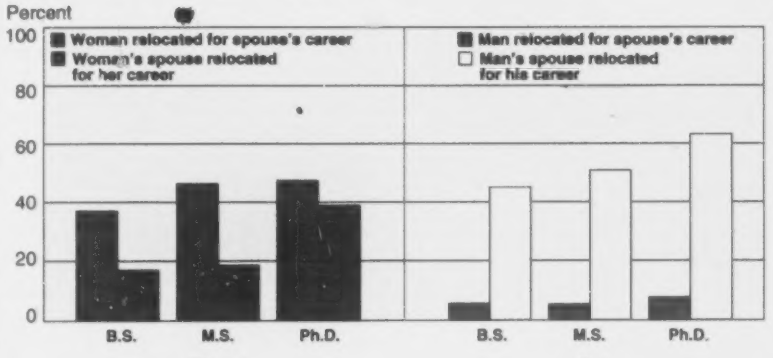


In the new survey, 89% of respondents were either married (77%) or living with a partner (12%). Women and men from 20 to 34 years old (the youngest age group surveyed) were about equally likely to be married (61% versus 64%); but above age 34, women were less likely than men to be married—68% of women versus 85% of men who were 35 to 49 years of age (the middle age group) and 59% versus 87% of those who were 50 to 64 years old (the older age group). Also above age 34, women were less likely than men to have children—63% versus 80% in the middle age group and 64% versus 92% in the older age group, suggesting that many of these women may have found marriage and/or children incompatible with a career. (In the younger age group, only 29% of women and 33% of men have children. These chemists, in the very early years of a career, may want to establish a career before having children.)

The majority of women in the survey (58%) were employed in industry, followed by 11% in government, 10% in non-Ph.D.-granting institutions, 9% in Ph.D.-granting institutions, and the remainder scattered among high schools, medical schools, and other places of employment. Men were spread nearly equally by employment: 60% in industry, 10% in government, 11% in Ph.D.-granting institutions, 9% in non-Ph.D.-granting institutions, and the remainder elsewhere.

Most married men (88%) and married women (82%) were supportive of their spouse's career. However, 61% of the men but only 10% of the women said their career was more important than their spouse's. Moreover, 25% of

Only women Ph.D.s and their spouses relocate nearly equally for each other's career



the women versus just 2% of the men deemed their spouse's career more important than their own. (The remainder held both careers equally important.)

Another gender difference that came to light is willingness to relocate to benefit a partner's career. Forty-four percent of the women, but only 7% of the men, said they had relocated to accommodate their spouses. Conversely, 59% of the men said their spouses had relocated for the sake of the man's career, whereas only 27% of the women claimed their spouses relocated for them. However, 32% of all men said their spouses were not in paid employment (only 7% of women said this) so, for some men, relocating very likely did not impinge on a spouse's career. Ph.D. chemists relocated more often than chemists with lesser degrees, and Ph.D. women chemists were more likely than other women to have their spouses relocate for them. Both men and women who relocated for the benefit of a partner had fewer job applications, job interviews, and job offers before accepting their most recent job than those who did not relocate for a spouse.

Compared with all other chemists, married women with children were less likely to be working full-time (82%) and more likely to be working part-time (11%). Overall, 89% of women worked full-time, including 98% of single women with children, 93% of single women, and 91% of married women without children. By comparison, 95% of men worked full-time, totaling 100% of single men with children, 98% of married men with children, 92% of married men with no children, and 91% of single men.

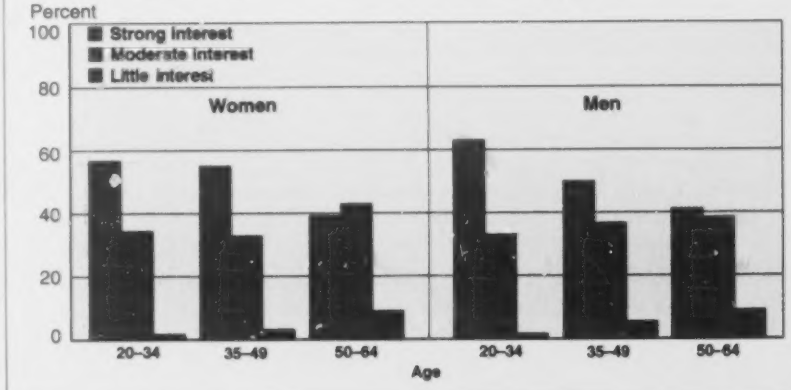
The survey found that interest in career was little influenced by degree, employer, gender, or family responsibilities. Instead, it was age-dependent, with younger chemists expressing the most interest. Respondents overall were committed to their careers—only 6% professed little or no interest, and, even among older chemists, more than 80% reported moderate to strong interest. It's noteworthy that 27% of women and 22% of men placed family or quality of life before career. Respondents didn't differ significantly in their perception of whether gender influences one's prospect of getting a job—53% of women and 55% of men believed gender has no effect. But some women (18%) and men (14%) believed their own sex to be an advantage, and 11% of women versus 5% of men believed it to be a disadvantage. Both men and women with primary responsibility for child care reported fewer job applications and job offers. Possibly these chemists narrowed their job search to positions they believed compatible with family responsibilities, or they lacked mobility, or both. Seventy-nine percent of women and 91% of men said training opportunities on the job are the same for men and women—but 20% of women and 5% of men said they are better for men.

When it comes to climbing the career ladder, however, only 47% of women and 73% of men said gender makes no difference. Here the same proportion of women (47%) and 19% of men said gender plays a role. The larger the size of the employer, the larger the proportion of women who believed this to be true. For example, 59% of women working for employers having 25,000 or more employees shared this opinion, compared with 24% of women working for employers having 50 or less employees.

When asked, "Have you encountered any instances of sex discrimination at work?" only 41% of the women, compared with 70% of the men, said they hadn't. And 43% of women and 13% of men said they had encountered sex discrimination to the advantage of men.

Women were also more likely than men to say they had encountered sexual harassment at work. Only 51% of the women, compared with 80% of the men, said they had experienced no instances of sexual harassment. A third of the women (34%) said they had experienced sexual harassment against themselves and 38% said they had observed it against other women. Nearly a fifth of the men (19%) said they were aware of sexual harassment against

Age, not gender, affects interest in career progression



women. (Only 3% of either sex said they had encountered sexual harassment against men.)

The survey also asked respondents how much extended leave they had taken for family reasons: 28% of women and 22% of men had availed of such leave. Of those who had, 77% of the women and 7% of the men cited child care as the reason. Women in all age groups had taken leave for child care, and the proportion of younger women who availed of this leave was only slightly more than in the other age groups. All of the men who took leave for child care were 34 or younger, no doubt reflecting the growing trend toward shared child care in dual-career families.

Leave time ranged from one month to eight years or more, with men and women in the younger age group more likely to have taken less time off—70% of these women and 67% of the men took six months or less. This fits with the times—young chemists in dual-career families are more likely to abbreviate their leave so as not to interrupt their careers. By comparison, nearly half (48%) of the older age women took three years or more of leave time, with 22% taking eight years or more, reflecting the tradition of the past, when the woman was more likely to be the homemaker. However, older women are more likely than younger women to have had several children, which also could account for their having taken more leave.

The survey also looked for distribution of employee benefits—flextime, sick leave, maternity and paternity leave, child care facilities, and others—among employers, and their impact on respondents. It found that with the exception of flextime, the larger the size of the employer the more likely a benefit would be offered and the more likely paid rather than unpaid leave would be offered. Sick leave was a more or less universal benefit—only 3% of respondents, some of whom could be self-employed, said they had no sick leave benefits.

But employers overall weren't so generous with maternity leave, and were far less generous with paternity leave. Only 57% of respondents who worked for the largest size employers (25,000 or more employees) said their employer offered paid maternity leave. And 26% of respondents who worked for employers of 50 or fewer people said no maternity benefits were offered. A scant 7% of respondents said their employer provided paid paternity leave, and only 19% said unpaid paternity leave was offered.

The ACS survey follows a similar survey of some 2600 British chemists conducted by the Royal Society of Chemistry in 1988 (C&EN, Oct. 21, 1991, page 31), and although there are some variations, the same trends are generally evident in both surveys. For example, in both the U.S. and the U.K., women are more likely than men to perceive sex discrimination and sexual harassment in the workplace, but American women are more likely than British women to say they have encountered either. And British men are more likely than American men to believe their sex an advantage for promotion.

As in the U.S., there was a large gender gap in how married British chemists rated the importance of their careers relative to their spouse's and in how they rated the importance of financial necessity to a career. Similarly, most British chemists considered training opportunities at work to be equal for both sexes, but gender was seen to influence promotion.

The results of both surveys seem to show that despite a strong interest in their careers, many married women are subordinating their careers to those of their spouses. Lower financial pressure, the desire for quality family life, and the demands of child rearing are arguments for compromise (although not exclusively on the part of the women). However, to the extent that gender influences promotion and curtails achievement, women are forced to compromise.

There's no neat formula for how to balance careers in dual-income families. As long as the prime child-bearing years coincide with the years in which careers are built, conflict, compromise, and hard choices are unavoidable. However, the ACS survey suggests that men are taking steps toward equity in sharing responsibilities, and that

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The Center will host the Second Annual Biocatalysis and Bioprocessing Conference in Iowa City on October 25–26, 1992. Industrial participants are invited to join us for a fall football weekend and to present a poster on biocatalysis/bioprocessing research. Information about the Center for Biocatalysis and Bioprocessing and the October conference is available from:

Professor John P. N. Rosazza, Director, c/o Ms. Beverly Palmer
Center for Biocatalysis and Processing, 318 Pharmacy Building,
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some employers are attempting to ease the way: Younger men have begun to take extended leave for child care, paternity leave has surfaced, and a number of men are relocating for the sake of their spouse's career.

A full report on the "1991 Survey of Domestic Status, Employment, and Attitudes of Men & Women ACS Members" will be issued by the ACS Office of Professional Services this summer. □

CAS cuts prices further for on-line database use

Chemical Abstracts Service will take another step in its shift away from time-based charging for use of its on-line databases on June 1. At that time, connect-hour charges for all CAS files on STN International, except learning files, will be lowered to $29. Connect-hour charges for the affected files currently are as high as $72. CAS lowered the connect-hour charge for the learning files to $15 earlier this year.

CAS began a shift away from time-based charging in 1988, placing greater emphasis on charges for the number of terms used in a search statement and answers displayed. In the June 1 price shift, search-term and time charges will be adjusted so that, allowing for the effect of system and file enhancements, the same searching patterns in CAS files on STN will yield about the same revenue to CAS. The new search-term charges will range from 45 cents in the CApreviews file to $2.85 in the Registry file. Charges for answer displays are not being changed.

Along with the price shift, CAS will introduce changes in its Registry file that will improve searching efficiency and searching speed for chemical names, classes of substances, and ring systems. Response time for all CAS files on STN International has been improved over the past six months and will be improved more in June. As a result of the system and pricing changes, the cost of any given search is likely to change—upward or downward.

James V. Seals Jr., director of marketing and corporate development for CAS, says CAS believes the price of an on-line search should reflect the value of the search to the user, not the length of time the user is connected to the host computer, which can vary greatly according to the speed of the user's equipment, the particular on-line service accessed, the particular database searched, and the time of day the search is made. "Our price shift is meant to place the charges where the value is—on the content, quality, and organization of the database, which are the result of the database producer's editorial processes," Seals says.

Largely because of connect-time pricing of on-line searches, Seals points out, many techniques and much technology have evolved to minimize the time a searcher is connected to a database to conduct a search. The response of most on-line service operators and database producers to these developments has been to increase connect-hour charges to compensate for the decreasing time the searcher is connected to the database. Seals says the very high connect-time charges that have resulted place the highest charges on a parameter that has no relationship at all to the value of the on-line search and discourage users from making full use of the interactive capabilities of on-line searching by pressuring them to minimize the time they are connected to a database.

"We believe that the lower connect-hour charges will enable searchers to browse in files, test their queries, review potential answers, and reformulate their search strategies at a thoughtful pace," Seals says. "We believe that by doing so, they will realize a much greater value for their on-line searching dollar." □

Fellowships available in solid-state chemistry

Corporate Research Laboratories of Exxon Research & Engineering Co. is continuing its sponsorship of a $7000 fellowship in solid-state chemistry. Selection of the fellowship recipient is administered by the Solid-State Subdivision of the ACS Division of Inorganic Chemistry. The fellowship will be presented at the 1992 fall ACS national meeting, and includes up to $500 to assist with the recipient's travel expenses.

The recipient of the fellowship must hold a tenure-track faculty position at an American university and not be more than six years beyond the Ph.D. degree at the closing date for nominations. The purpose of the grant is to support solid-state chemistry as a recognized discipline and to encourage

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